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Wavelet Denoising of Mobile Radiation Data

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Wavelet Denoising of Mobile Radiation Data
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Abstract

The FY08 phase of this project investigated the merits of video fusion as a method for mitigating the false alarms encountered by vehicle borne detection systems in an effort to realize performance gains associated with wavelet denoising. The fusion strategy exploited the significant correlations which exist between data obtained from radiation detectors and video systems with coincident fields of view. The additional information provided by optical systems can greatly increase the capabilities of these detection systems by reducing the burden of false alarms and through the generation of actionable information.

The investigation into the use of wavelet analysis techniques as a means of filtering the gross-counts signal obtained from moving radiation detectors showed promise for vehicle borne systems. However, the applicability of these techniques to man-portable systems is limited due to minimal gains in performance over the rapid feedback available to system operators under walking conditions. Furthermore, the fusion of video holds significant promise for systems operating from vehicles or systems organized into stationary arrays; however, the added complexity and hardware required by this technique renders it infeasible for man-portable systems.

Introduction

Challenges of Mobile Radiation Detection

The task of searching for illicit radiation sources from a moving platform can be daunting. The highly dynamic nature of ambient radiation combines with statistical fluctuations and chaotic shielding conditions to create the complex temporal signals reported by moving detectors. Though complicated, this signal is also rich in information which must be exploited in order to realize the full potential of a mobile detection system. Previous phases of this project utilized wavelets to characterize structures in the temporal signal of moving detectors and found wavelet analysis to be a powerful tool for thoroughly mining this source of information.

Experienced system operators can often interpret temporal signals to gain significant insight, e.g. this peak suggests a quickly moving source or these features suggest intermittent shielding by passing objects. During the current project, wavelets have proven to be a quick and effective method for characterizing features in mobile radiation data from diverse detector architectures. This capability allows the exploitation of orthogonal data, such as video cameras, and the automation of these expert analysis techniques. These automated routines could be used to potentially reduce false alarm rates as well as effectively identify targets for secondary screening.

Increased performance would be achieved through the reduction of false alarm rates, such as the dismissal of alarms due to extended sources. Furthermore, the utilization of video systems would increase overall system performance through the generation of actionable information for system operators. The burden of alarm resolution would be drastically reduced if a short list of specific objects of interest were identified through object tracking performed on the coincident video feed. Current system operators face the daunting task of attempting to identify targets in cluttered and dynamic environments with little more than intuition.

Sensor Fusion Strategy

The capabilities of mobile and re-locatable systems are currently greatly diminished by the challenges associated with dynamic shielding and natural variations in background radiation; challenges which are compounded when these systems are operated while in motion. To address these challenges and realize the full potential of these systems, the current project sought to exploit the heavy correlation which exists between the signals from radiation detectors and video systems with coincident fields of view.

This relationship is illustrated in Figure 1 where the observed signal from a radiation detector has been impacted by obstacles present in its environment. These obstacles are clearly evident in the photograph of the detector's field of view. The detected radiation profile was produced by a source located in a vehicle (not shown in the image) traveling along the road depicted in the photograph. The four dips observed in the signal profile are due to the two trees and two water-retention tanks visible in the image. As the source traveled behind these objects the radiation signal was occluded, just as the image of the vehicle containing the source would have been obstructed from a camera's view.

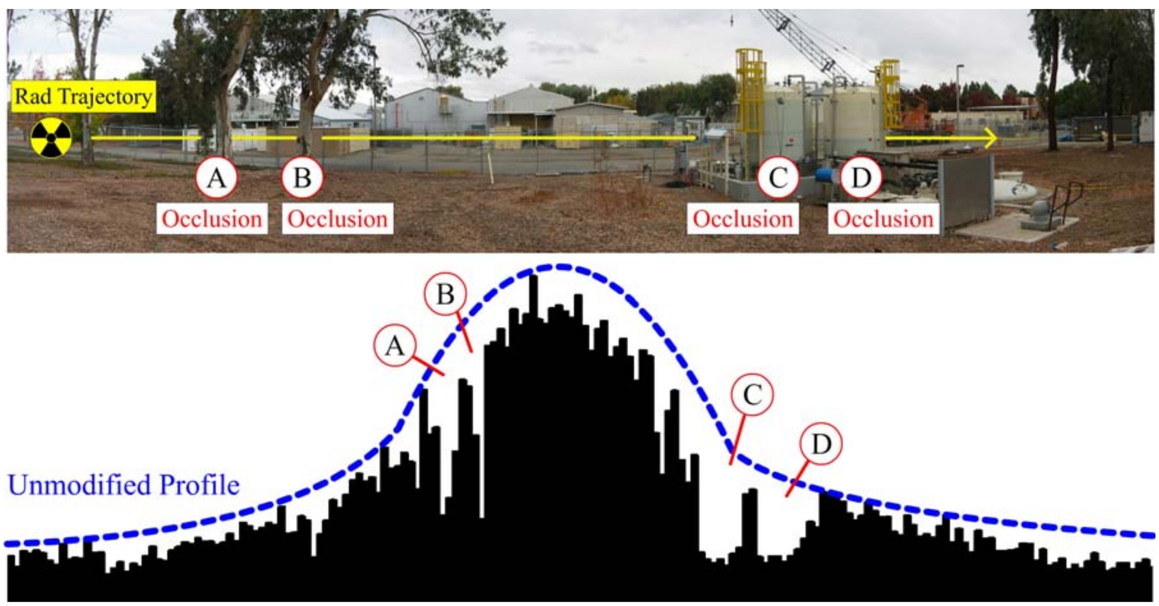

Figure 1: Top: An image of the field of view of a radiation detector showing the road along which a radiation source traveled as well as four obstructions**. Bottom:** The detected radiation profile from the source as it traveled along the road. The unmodified profile is shown by the dashed blue line while the occlusions which correspond to each obstruction have been labeled with red circles.

Combining the information content of the detected radiation profile with the object tracking capabilities of a video system produces a powerful targeting tool. This tool allows the number of potential targets to be reduced based on incompatibility between object trajectory and the detected radiation profile. As shown in Figure 1, the driving influence of a detected radiation profile is positional relationship; the position of the source, the detector and any intervening shielding objects.

A simple method for quantifying and exploiting positional relationships is by arranging a detector and a video camera so that their fields of view coincide, see Figure 2. For vehicle borne detection systems, the coincident field of view allows the positional relationship between possible targets to be easily evaluated based on lateral distance from the center of the picture. With this configuration, video enhanced detection systems can effectively performing proximity imaging by utilizing the dynamic nature of the environment they are navigating.

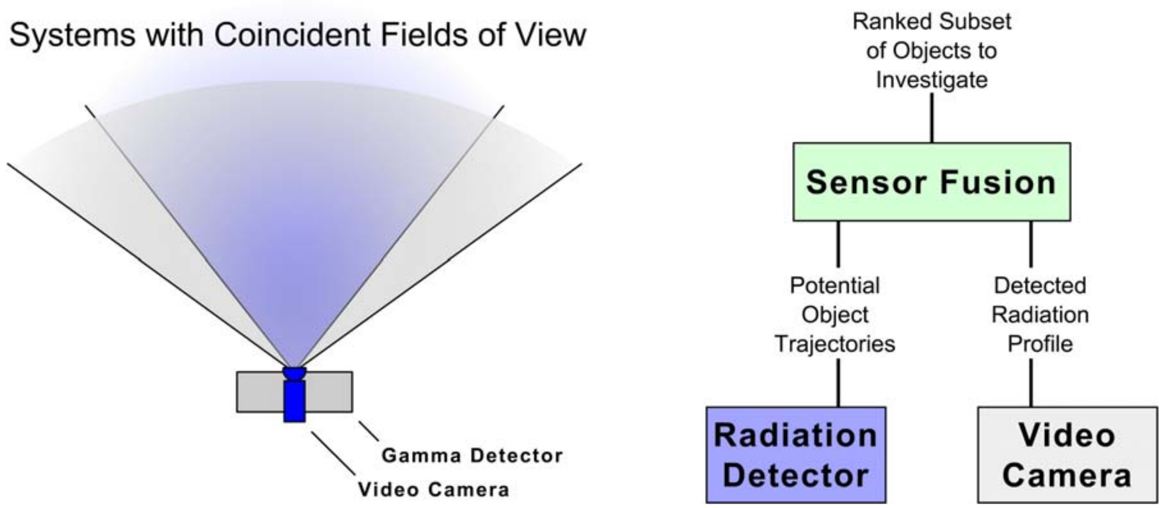

Figure 2: Left: A schematic of a video camera and radiation detector configured to have coincident fields of view. **Right:** A schematic of the sensor fusion algorithm.

As shown in Figure 2, the sensor fusion strategy incorporates three modules: radiation detector, video system and fusion algorithm. The radiation detector reports a smoothed radiation signal, while the video system reports the trajectories of tracked objects. The sensor fusion algorithm then compares the weighted object trajectories with the radiation profile and returns a ranked list of the best candidates to the operator.

Results

In order to evaluate the algorithm with real data, an experiment was conducted utilizing a NaI detector mounted in a van. A video system with a coincident field of view was positioned as described in Figure 2. The detection system was then driven past a series of scenes which included a concealed 30 mCi ^{137}Cs source. The scene shown below, Figure 3, was acquired with the vehicle traveling at roughly 25 mph.

Figure 3: A photo mosaic of a scene analyzed with the sensor fusion system. The radiation source is located inside the parked vehicle closest to the center of the image.

<u>Radiation Detection</u>

The radiation detection subsystem recorded the total counts detected as a function of time, though energy binning could be used to further isolate the desired portions of the signal. The sample rate of the detector (7 Hz) was slower than the sample rate of the video system (30 Hz). To compensate for this, interpolation was performed to stretch the dimension of the radiation data to match the video data. The radiation signal was then smoothed using a biorthogonal wavelet. An example of the result is shown in Figure 4 where each point in the radiation profile has been associated with a frame in the video.

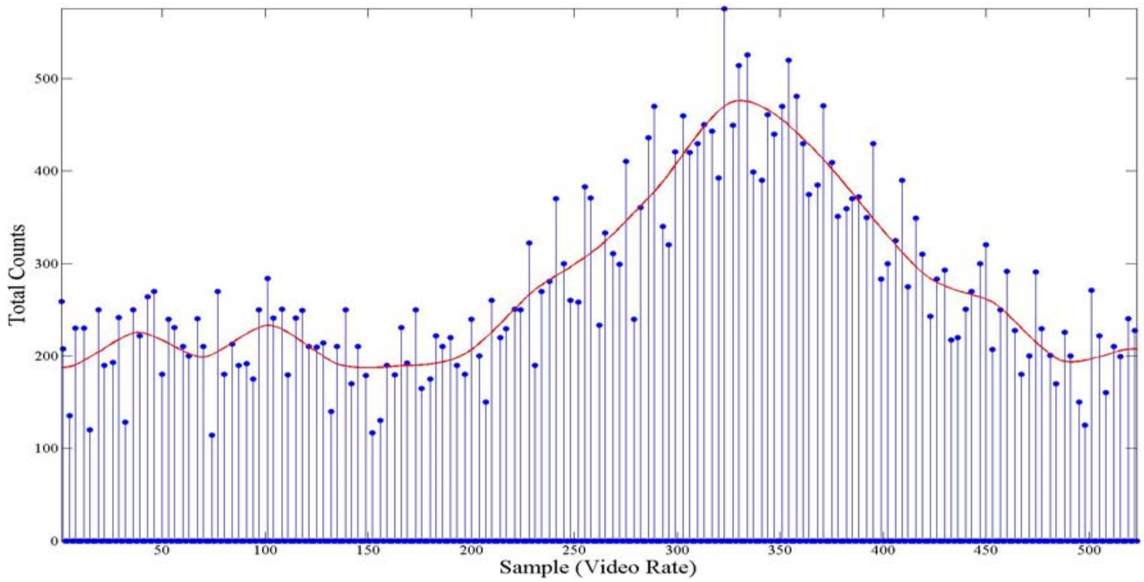

Figure 4: An example of the interpolated and smoothed radiation data.

Video Tracking

The video system with the coincident field of view was used to perform tracking on objects which passed in front of the radiation detector. While object tracking algorithms are readily available for stationary camera systems, there are no ready-made solutions for object tracking from a quickly moving camera; particularly a camera pointed out the side of a vehicle travel at 25 mph. To compensate for this lack of existing solutions, a new tracking algorithm was designed.

Figure 5: Left: The track created by a portion of the van containing the radiation source, the image shows the frame of video containing the first contour while subsequent contours are shown moving to the right. **Right:** A track created by an individual standing in the scene.

The tracking algorithm defined objects as regions of similar color, or contours. The contours were then associated with similar contours in following frames of the video. These connected contours were then accumulated in tracks. This approach avoided the problem of correctly defining real objects, such as vehicles, by tracking component parts such as windshields or tires. An example of the contours which were connected into tracks is shown in Figure 5. Notice that the algorithm has tracked the van on the left by a bright spot below its rear window. This van was tracked by multiple color regions, including the shadow underneath it, each region was treated individually by the fusion algorithm. This redundancy allowed the van to be tracked well in spite of changing perspectives.

For the data from then scene shown above, 370 objects were tracked. Each of the many tracks was converted into a trajectory which contained the centroid of the contour as a function of video frame. These trajectories where then compared to the detected radiation profile by the fusion algorithm.

Sensor Fusion

The data obtained by the radiation detection subsystem and the video tracking subsystem were combined by the sensor fusion algorithm. The smoothed radiation data was normalized and used as a template for sorting and scoring the object trajectories. Trajectories were weighted by a normal distribution whose maximum coincided with the center line of the video system. Due to the coincident fields of view, this location also coincided with the maximum efficiency of the radiation detector. These weighted trajectories were also normalized. A set of sample comparisons are shown in Figure 6.

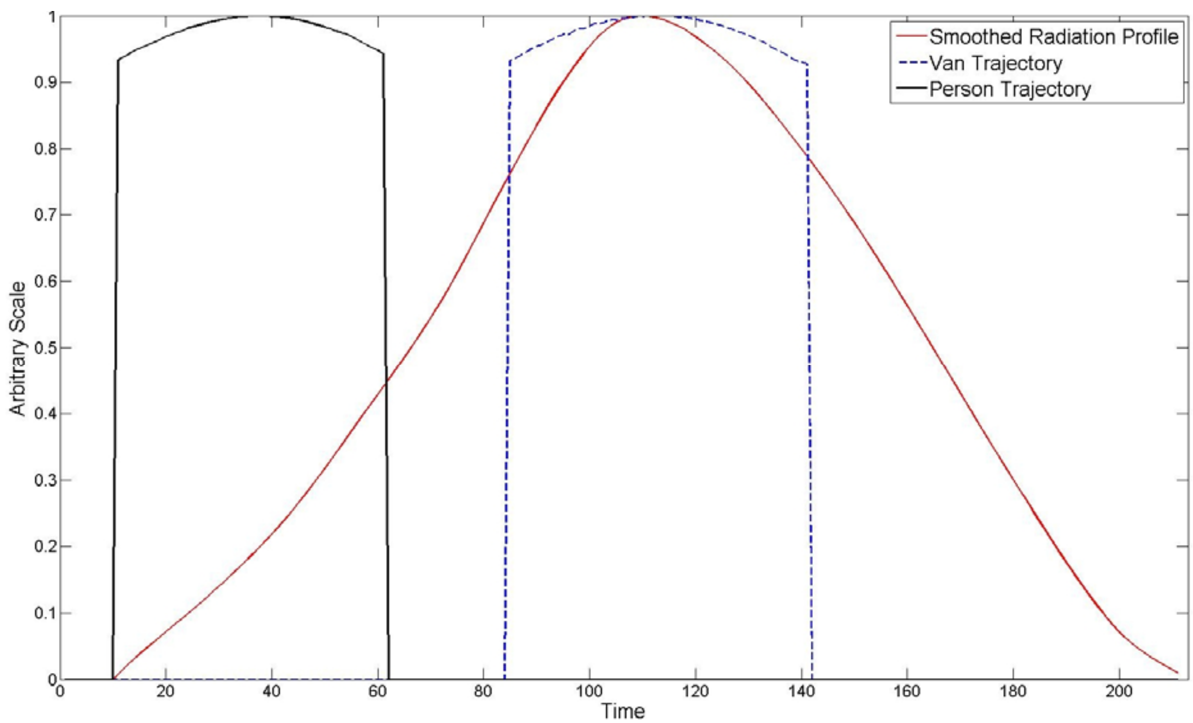

Figure 6: A plot showing the smoothed and normalized radiation profile (red) as well as two weighted object trajectories. The black trajectory belongs to the individual shown in Figure 4 while the blue dotted trajectory belongs to the van containing the source, also shown in Figure 4.

In order to identify the subset of objects most likely to contain the source, each trajectory was given a score. This score was simply the dot product of the radiation profile and the negative of the trajectory under consideration. A more sophisticated fusion algorithm which accounted for the broken trajectories of occluded objects was designed during this project but was not implemented due to time constraints. However, the method which was employed performed well with 3 of the top five objects for inspection belonging to the van containing the source. Further effort optimizing the algorithm could significantly improve performance.

Conclusions

Wavelets have proven to be a powerful tool for analyzing data from vehicle borne radiation detection systems. However, performance remains limited due to false alarm rates caused by legitimate sources of radiation. The current work demonstrated a novel approach to mitigating these alarms by exploiting the strong correlation which exists between radiation detectors and optical sensors with coincident fields of view.

Under the conditions encountered by vehicle borne radiation detectors, the observed signal is driven by the positional relationship between the source, the detector, and any intervening objects. As a result, the time series radiation data can provide insight to the positional relationship between the detector and the source. This information can then be used to narrow the list of potential objects to target through fusion with a video tracking system.

The fusion of video tracking systems and radiation detection systems will allow performance gains through false alarm rate reduction as well as increased system efficacy due to the generation of actionable post-alarm targeting information. However, in order to realize these performance gains the fusion must be implemented in real-time which would require algorithm optimization and possibly specialized hardware.